JOURNAL & PROCEEDINGS

OF THE

ASIATIC SOCIETY OF BENGAL.

New Series, Vol. IV.

1908.

CALCUTTA:

PRINTED AT THE BAPTIST MISSION PRESS, AND PUBLISHED BY THE ASIATIC SOCIETY, 57, PARK STREET, CALCUTTA.

1910.

DATES OF PUBLICATION.

Journal, pp.	1-30	Proceedings, pp.	i-iv	20th February, 1908.
,, ,,	31-80	,, ,,	v-lxxvi	22nd April ,,
,, ,,	81-150	,, ,,	lxxvii-lxxx	26th May ,,
,, ,,	151-246	,, ,,	lxxxi-lxxxiv	25th June ,,
,, ,,	247-292	,, ,,	lxxxv-lxxxvi	4th August ,,
,, ,,	293-354	,, ,,	lxxxvii-c	26th September ,,
,, ,,	355-390	,, ,,	ci-cvi	29th October ,,
,, ,,	391-446	,, ,,	cvii-cx	3rd December ,,
,, ,,	447-496	,, ,,	cxi-cxii	18th ,, ,,
,, ,,	497-592	,, ,,	cxiii-cxx	11th March, 1909.
,, ,,	593-656	,, ,,	cxxi-cxxiii	21st April ,,

ERRATA.

Page 216, line 3 of table, *for* 5·12 *read* 35·12.
,, 226, ,, 1 from bottom, *for* duophobus *read* deiphobus and *for* Halictu *read* Halictus.
,, 230, ,, 31, *for* great-flower visitor *read* great flower-visitor.
,, 230, ,, 4 from bottom, *for* Anthphora *read* Anthophora.

DIRECTIONS FOR BINDING.

The pages of the Journal should be bound first: they are numbered in arabic numerals. The pages of the Proceedings should follow: they are paged consecutively in roman numerals. The Index is paged in continuation of the Proceedings.

Plates	i-iii	to face page	50.
,,	iv-v	,, ,, ,,	94.
,,	vi-vii	,, ,, ,,	110.
Plate	viii	,, ,, ,,	142.
Plates	ix-xiv	,, ,, ,,	166.
,,	xv-xvi	,, ,, ,,	488.

or all to be placed at the end of the volume.

LIST OF PAPERS

IN THE JOURNAL.

JOURNAL & PROCEEDINGS

OF THE

ASIATIC SOCIETY OF BENGAL.

Vol. IV, No. 1.

JANUARY, 1908.

CALCUTTA:

PRINTED AT THE BAPTIST MISSION PRESS, AND PUBLISHED BY THE ASIATIC SOCIETY, 57, PARK STREET.

1908.

Issued 20th February, 1908.

List of Officers and Members of Council

OF THE

ASIATIC SOCIETY OF BENGAL

For the year 1908.

President:

The Hon'ble Mr. Justice Asutosh Mukhopadhyaya, M.A., D.L., D.Sc., F.R.S.E.

Vice-Presidents:

T. H. Holland, Esq., D.Sc., F.G.S., F.R.S.
G. Thibaut, Esq., C.I.E., Ph.D., D.Sc.
Mahamahopadhyaya Haraprasad Shastri, M.A.

Secretary and Treasurer:

General Secretary:—Lieut. Colonel D. C. Phillott.
Treasurer:—J. A. Chapman, Esq.

Additional Secretaries:

Philological Secretary:—Lieut. Colonel D. C. Phillott.
Natural History Secretary:—I. H. Burkill, Esq., M.A.
Anthropological Secretary:—N. Annandale, Esq., D.Sc., C.M.Z.S.
Joint Philological Secretary:—Mahamahopadhyaya Satis Chandra Vidyābhūṣaṇa, M.A.
Medical Secretary:—Major L. Rogers, M.D., B.Sc., I.M.S.
Numismatic Secretary:—H. N. Wright, Esq., I.C.S.

Other Members of Council:

T. H. D. La Touche, Esq., B.A., F.G.S.
Harinath De, Esq., M.A.
J. A. Cunningham, Esq., B.A.
Lieut.-Colonel W. J. Buchanan, M.D., I.M.S.
H. G. Graves, Esq.
Lieut. Colonel G. F. A. Harris, M.D., F.R.C.P., I.M.S.
Babu Monmohan Chakravarti, M.A., B.L.
Abdulla al-Mamun Suhrawardy, Esq., M.A., LL.D.

49. The Kosi River, and some lessons to be learnt from it.

By Captain F. C. Hirst.

Speaking of the work of man, in contrast with that of nature, in the basin of the Mississipi River, Chamberlin and Salisbury, two eminent American scientists, say[1]:—

"The millions of industrial freightage in the Mississipi basin, "are, to-day, not wholly incomparable with the drainage transport-"ation of the same area a century ago. . . . It is doubtful whether "some parts of this region suffered as much erosion in the "preceding five centuries as they have during the last one. . . . In "the light of considerations such as these, man may be well "regarded not only as a potent geological agent, but dangerously "so to himself. The hope is that the intelligence that has "wrought a change in surface conditions, serviceable for the "present, but dangerously so to the future, will be so enlarged as "to inspire a more intelligent control of surface conditions which "shall compass the future welfare as well as transient benefit."

The Mississipi and Ganges (with such parts of the feeders of the latter as occupy a portion of the region known as the Gangetic plain) have much in common, and the advice tendered by the two authorities quoted above applies with greater force to India than to America, because the conclusions arrived at by American experts are based on the results of a scientific examination of the Mississipi River, executed with greater care and in more minute detail than similar operations in any other part of the globe. Where the authorities in the United States have ample information to guide them in dealing practically with river questions, we, in India, are compelled to resort to speculation, based on the analogy of the rivers of other countries which, from time to time, have received careful attention. Since, however, all rivers flowing through plains similar to the Gangetic plain behave in much the same manner, it is not impossible to form a very fair idea of how far it is, or is not, at present, advisable to tamper with such a stream as the Kosi along its reaches in the plains themselves.

The Kosi River is well known to most people in Bengal as a scourge to the districts of Bhagalpur and Purnea, and, from time to time, what may be considered as futile efforts to mitigate, or even annul, the devastating effects of the river have been attempted; the means adopted have invariably been embankments, which, although they may have afforded temporary relief in certain places, cannot be considered to have justified the

[1] Chamberlin and Salisbury, "Geology and its processes," p. 620.

expenditure which their provision and maintenance entailed and still entail. The history of the endeavours to keep the river under control appears to go back a very long way; although there is no direct evidence to show the date of construction of the Bir Band (*vide* diagram No. 1), which originally appears to have been built along the right bank of the Kosi as a protective work, that date is certainly several centuries back. The Band extends for many miles roughly along Longitude 87° East, and to this day is, in places, in a very fair state of preservation. It bears strong evidences, however, more particularly south of the Bengal and North-Western Railway, of having been broken from time to time, and the frequent gaps in it show that it has suffered considerably either at the hands of the Kosi, or—and this is just as likely—from the ravages of other rivers lying to the west of the Band; no waterways appear to have been left through the Band, and to-day it stands as a relic of a useless attempt to tamper with the movements of a river which has since shown itself to be the master of the situation. The above remarks are based on the assumption that the Bir Band is a river-protection work; there are those who look on it as a boundary fortification; if this latter view is correct, there would assuredly be portions of the Band raised above its ordinary level to serve as forts, blockhouses, or spy-posts. There is no sign of any such elevations in the whole length of the Band, and it may therefore, I think, be accepted without demur that the embankment was built to protect certain areas from riverain depredation.

In recent times, on the left bank of the Kosi, in the Purnea District, private enterprise has copied the work of the makers of the Bir Band, giving temporary relief, which, as will be seen later, is probably a menace to "future welfare." At the point at which the Kosi enters the Ganges considerable training works have been erected by the Bengal and North-Western Railway Company; these are of modern type, and a description of them is beyond the scope of this note.

In all the attempts referred to above, perhaps with the exception of the modern works at the mouth of the Kosi, which lead the river into the Ganges below a bridge, no effort appears to have been made to provide for suitable emergency or other outlets through the embankments; this point is significant, and its results will be explained in detail hereafter.

About eighteen months ago, an officer of the Public Works Department was placed temporarily on special duty to make a full enquiry into the movements of the Kosi River, and to report what steps could be taken to "muzzle" the river; for some reason not known to the writer, before this officer had carried out any of the considerable amount of field work which a report would have necessitated, he reverted to his substantive appointment, and the matter has not since been reopened. From time to time the Purnea Local Board has enquired into the subject, but no serious steps have been taken, as far as I am aware, to carry into practice the many and varied suggestions put forward by those who had

a local knowledge of the river's action. Mr. Shillingford,[1] some years ago, published a pamphlet on the river, advocating the theory that it behaved somewhat like a swinging pendulum which hung from the point at which the Kosi leaves the hills and enters the plains; after gradually swinging further and further eastwards, it was assumed that a series of westward oscillations would occur. Mr. Shillingford believed that the lateral movement, after a definite period, became reversed, and in this manner the whole area of operation of the river was covered, time after time, by a succession of its beds. This theory is doubtless partially correct, but does not hold good altogether; recent writings, mostly published since Mr. Shillingford's time, show that a perpetual oscillation theory cannot be accepted under the circumstances.

Mr. H. Green, the Public Works Officer referred to as having been placed on special duty to examine the Kosi some months back, asked me, since I had then very recently finished a survey of the river in British territory, if I could give him any information which would be of use to him; but although I had been studying this river for some time, I did not feel competent to give any opinion which would be of practical use to Mr. Green; further, since I considered the embankment system to be an erroneous one for a river like the Kosi, and since I believed that the Public Works Department would, if it attempted training operations, be compelled to resort to rigid embankments, I decided that it would be best to give no opinion at that time, but to continue the study of the river. This note is the result of the further study just alluded to, and although it is somewhat superficial, the evidence used shows clearly that the time for the rigid training of the Kosi is at a considerable distance ahead of us. In arriving at this conclusion the reasoning made use of gives material for a discussion on other matters connected with the rivers of Bengal, Eastern Bengal and Assam, the importance of which does not appear to have been fully realized.

The training of rivers is a subject which has received much attention from engineers for many centuries past; the Phoenicians and the ancient Egyptians inaugurated a science which in the last 300 years has resulted in the launching of projects having far-reaching effects. The Chinese, however, probably give us the best examples of the deplorable results which wrongly-designed attempts to benefit one generation have had on posterity; an important river, in the act of fulfilling a definite programme of land construction by the deposition of the sediment carried in its waters, was forced into a fixed bed, and maintained there by the closing, with embankments, of the natural outlets which permitted flood waters to deposit the matter which they held in solution or suspension, on lands which sadly needed it. Each succeeding generation has been compelled to raise the height of the embankments, to make them keep pace with an ever-increasing flood

1 "Journal" Asiatic Society, Bengal, Vol. xliv, part 1, page 1. See also Proceedings, 1898, page 41.

level; at the present time the river runs many feet above the surrounding country, while the low lands have been drained and cultivated and support a dense population increasing year by year; an unusually heavy flood breaks down or overtops the embankments, and the pent-up waters deal death to the posterity of those who, originally in good faith, prepared the way for disaster.

The terrible results of the embankment system in China should serve as a warning to Indian engineers; it is very doubtful if the warning has yet been taken, and it is more than probable that the heavy floods which in very recent years have devastated several of the North Bihar districts are mainly, if not entirely, due to the prevalence of embankments in those parts; any training works carried out with the object of forcing a river of the nature of those under discussion, however small that river may be, to follow and maintain a course which it has no tendency to assume, must be contrary to the intentions of nature herself. An embankment, with little or no waterway through it for the carrying off of flood waters, is a glove thrown in nature's face—an insult which she has not yet been known to leave unavenged.

I am told on good authority, by those with mature experience on the spot, that in North Bihar, the flood levels have risen in one district over eighteen inches in thirteen years, and in another over three feet in twenty years; the latter district is Darbhanga, where recent floods have done inconceivable and irreparable damage; the former district is Muzaffarpur, the figures being those of Mr. Disney, District Engineer, up to 1898. Since that date the flood levels appear to have shown signs of further rising. Further afield we find similar troubles, Midnapore being a fair example; there, I am informed, lands which were dry a few years back are now perennially inundated. Many other instances of floods being on the increase might be quoted, and it is very significant that in nearly every case embankments abound in the distressed tracts. I admit that there are well-known cases in which floods do serious damage although embankments do not exist in the neighbourhood, or, if they exist, they are too insignificant to be serious factors in the trouble; but as far as I can ascertain, there is no recorded case in which floods appear to be increasing in intensity in which embankments do not exist close at hand, and it seems to be pretty certain that where floods occur in localities in which there are no embankments, those floods do not appear to be becoming more violent as years go on. The natural inference is that the embankment is to blame for increases in floods under most circumstances.

There is a difference of opinion as to the actual effect of embankments on the beds of streams, some authorities holding that although the bed of the stream is undeniably raised, there is a limit to the possible rise. I do not consider that sufficient proof has yet been brought forward to show that a limit exists, and whilst speculation on the point remains, we can but assume that the damage which may occur before the limit is reached is infinitely worse than that which would be caused, in the interim,

by floods of a more or less fixed high level. Embankments designed to keep every drop of flood water from protected lands are inadvisable, but it may be admitted that if the design of the embankments permits certain flood waters to wander over protected areas, those embankments may be of use, and nature may, not unreasonably, show no resentment to their growth; in other words, it may, at any time of unusual flood, be necessary to admit flood waters to so-called protected lands even to the extent of seriously inundating those lands.

The catchment area of the Kosi, in the Himalayas, has been estimated by Colonel Burrard, F.R.S.,[1] at about 23,992 square miles; the river collects its water from mountains, of late elevation, geologically speaking, subjected to a heavy annual rainfall. In point of area of hill catchment, the Kosi is considered to be the third largest of the Himalayan Rivers, ranking second only to the Indus and the Brahmaputra. The Kosi, for the last 100 miles of its course, runs nearly in a straight line, lying almost due North and South, from the point at which it debouches from a defile in the Siwaliks (or outer Himalayas) to that at which it empties itself into the Ganges, opposite Colgong. This 100 miles occupies a bed, or rather a series of beds, on the plain, which slopes, with a slight tilt from West to East, from North to South. The tilt of the plain of the Ganges in this neighbourhood is of utmost importance. At first sight it would be natural to expect the river, in British territory, to take a course bearing somewhat east of South; in bygone days the river actually took such a course, but, from its original position (roughly South-east, and possibly still more East than South-east), it has gradually moved westwards until it assumed its present course, which it probably maintains mainly by virtue of the large volume of water which it carries in the rains.

The subject is perhaps best approached by considering the Kosi River as it was, as it is, and as it will be; history, tradition and science combine to give us a good idea of the past, the present is known, and the future history, thanks mainly to the careful attention given to the subject of the movement of rivers by the United States Government, can be foretold, I believe, with a considerable degree of accuracy.

The history of the river has been very greatly affected by the gradual depression of the rock floor underlying the Gangetic plain, owing, perhaps, to the amount and the weight of the silt which for ages has been accumulating on the surface. Some scientists aver that the weight of silt deposited is sufficient to bend inwards the more or less elastic crust of the earth: this depression may have caused a rise in land elsewhere, and the rise, in the case under discussion, would have occurred in the Siwalik Ranges. It is, however, much more probable that the Siwaliks, which are known

[1] Burrard and Hayden—"Geography and Geology of the Himalaya Mountains and Tibet," Part III, page 131; see also page 149 *et seq.* In discharge, as well as area of hill catchment, the Kosi is considered by three authors to be the third largest of Himalayan Rivers; but it is admitted that the figures on which the discharge has been calculated may be inaccurate.

to have been rising within a very recent period, and may still be rising, owe their elevation to the thrust from the North which has elevated the Himalayas. History, tradition, and even ocular evidence support the theory of recent elevation of the Siwaliks, and it is unnecessary to enter further into the scientific side of the question in this note.

Diagram No. 1 shows, in black, the country just North and South of the main channel of the Kosi River as it exists now, within the line of the hills, and, in red, the same area as surveyed by Rennell and published in his famous atlas of 1783; the positions of towns marked in red are identical in both the old and recent maps and they have been used as the fitting points between the two surveys; there are, undoubtedly, many discrepancies in Rennell's maps, but the area covered by Diagram No. 1 can, at any rate up to the hills, be considered as tolerably accurate, since the positions of most of the main towns and villages are correct according to our existing maps. The area inside the hills is not as correct as it might be, but, fortunately, in 1767 Kinloch marched up the Comla (Kamla) River and mapped his route, and it is from Kinloch's work that Rennell put in that portion of his map. The distance [from Mynathpur to the point marked X (in red) in Rennell's map] agrees almost exactly with the accepted distance between Mynathpur and the junction of the Likhu with the Kosi. Admitting, then, that Rennell's map is somewhat out in Azimuth (as will be seen later, it does not follow that this is the case), it is clear that inaccuracies which are of any practical importance need not be anticipated in direct distances in Rennell's map in this vicinity. A further point in favour of Rennell is that our own maps of this neighbourhood are not based on a careful detailed survey.

Examining the diagram, we find that in 1767 the Comla (Kamla) flowed right through the Siwaliks, while to-day it rises in them; further, on reaching the point X, Kinloch noted a strong stream flowing from the North, probably the main stream of the old Kamla, and he found (or he would surely have noted it) no stream running to the east as the main Kosi now runs. From X he turned westwards along the red stream shown in the diagram, and having followed it for some distance, he returned to Mynathpur by the road he had gone by. Now Rennell shows the west arm of the old Kamla (the stream last mentioned above) as rising east of the present junction of the Tamba and Kosi, and here we meet the only really inaccurate point in Rennell's map; the inaccuracy can, however, be explained by the fact that Kinloch did not follow that stream to its source and that he may have given it an imaginary source in high land into which it disappeared from his view. Be this as it may, I think that there is little doubt but that the stream carried the water of the Tamba Kosi to the point X, and there, receiving the waters of the Likhu Kosi, turned southwards, and was known as the Kamla for the rest of its course.

We may therefore suppose that the Likhu Kosi was the upper direct feeder of the Kamla, but the difference between the point X

and the junction of the Likhu and main Kosi still needs explanation. In 1767 no stream ran eastwards from the junction just mentioned, while a very strong stream now runs in that direction and intercepts the waters of the Likhu and Tamba Kosis; the natural tendency of the Likhu Kosi's mouth under the new conditions would be to move eastwards, and it is possible that Rennell's map is not, after all, out in Azimuth.

In addition to the evidence of Rennell's map, there are other points which support the conclusions drawn from that map.

We have said that the Tamba Kosi in 1767 very probably flowed into the Kamla; when it is remembered that different languages are spoken on either side of the Siwaliks, that K. and T. are almost, if not actually, linguistically interchangeable letters; and lastly, that the nomenclature of many Himalayan rivers is at present a controversial point, it must be admitted that there is a great similarity between the names Tamba and Kamla; this similarity is emphasized by the existence, in the Purnea District, of a stream also known as the Kamla which is in direct prolongation of the upper course of the most easterly feeder of the Kosi, *viz.*, the Tamru [1]; here we find almost an identical parallel with the former example.

A further and even more striking case exists; the Tiljooga River now flows in imaginary prolongation of the Dudh Kosi; if the Siwaliks did not exist, the two rivers would probably be one. At one time this appears to have been the case; for, if we look to the north of the Choorea Ghatee Hills we find a stream called the Trigooja crossing the dotted red line between the Dudh Kosi and the Tiljooga; the elevation of the Choorea Ghatee Hills [2] would cause the appearance of such a stream as the Trigooja, and it is very remarkable that its name should be that of what I assume to have been a stream which once crossed the present bed of the Trigooja at right angles.

Tradition in North Bhagalpur states that, in the past, streams of much greater size than the existing rivers flowed from the north; a careful observer may notice that the undulations which occur in this part have, although long since smoothed by wind and weather, still the appearance of remains of old beds of important streams; in other cases, such as the Balan River, a stream now almost dead, runs in a bed which was obviously made for a river of very much greater importance.

Science, history, tradition and ocular demonstration all agree

---

1 Burrard and Hayden, on page 150. Part III, of their "Geography and Geology of the Himalaya Mountains and Tibet," give the following sources to the different names used for this river: Tamru (Montgomerie); Tamor (Hodgson); Tambur (Hooker). The authors themselves accept the name Tambar.

2 Burrard and Hayden—"Geography and Geology of the Himalaya Mountains and Tibet," Part III, footnote to page 149.

"The affluents of the Kosi have not been forced to converge by the ridges running southwards from Kinchinjanga and Gosainthan, but by the recent rise of the lesser Himalayan range across their path."

in pointing to a recent elevation of the Siwaliks, and I hope that sufficient evidence has been brought forward to convince the reader that the feeders of the Kosi within these hills, were, in very recent times, independent or semi-independent rivers flowing southwards through the area now occupied by the Siwaliks.

At first sight it may appear to be strange that of all the feeders of the Kosi River, north of the Siwaliks, only one, the Arun, has maintained a way through those hills to the plains; there are several reasons for the phenomenon; first, there are falls at the point of egress from the hills, and the elevation at that point has been insufficient to check the course of the river, or possibly the erosion of the river has been able to keep pace with the elevation. Secondly, from time to time, the Arun has been reinforced by the waters of other streams on each flank, and this reinforcement must have had a considerable effect both on the wearing power and the head of water passing through the gorge at which the Arun changes its name to the Kosi. Thirdly, the Arun is a much more powerful stream than any other feeder of the river The second explanation is most probably the true one.

It is reasonable to suppose that the growth of the Siwaliks still continues, and it seems possible, but improbable, that the exit from the hills may eventually be closed. At the worst the closing would be temporary, for, if once blocked, the dammed-up waters would soon, having raised themselves to a sufficiently high level, re-establish the flow towards the plain. It is hardly likely, I think, that the rate of elevation to-day is sufficient to again cause the damming up of the river.

The changes detailed above are so far-reaching, startling, and contrary to the very slow processes of nature, as generally accepted by geologists, that, before proceeding further, it may be well to consider whether other agencies, besides that of slow growth due to the depression of the plains, have not helped to effect those changes.

Roughly speaking, a slow elevation of one foot in a century would, in a hill, be geologically rapid; from the term "slow elevation" I exclude the effects of a catastrophe. We do not know, unfortunately, how many feet were added to the height of the Siwaliks before the head-waters of the old Kamla were deflected towards the Arun. The minimum growth must have been several feet, and it is possible that even a fifty-foot rise may have been insufficient to cause the deflection. We have had earthquakes in the interval between Kinloch's time and our own, but since 1762 no sudden earth movement has occurred which would have caused the changes under discussion; Kinloch in 1767, or five years after the greatest earthquake which India has known in modern times, found a state of affairs existing which has altered very materially in the last 140 years, and, although the shock of 1762 may have been one of the ruling factors in the commencement of the changes, it cannot be altogether responsible for them, unless it caused a continued imperceptible growth which continued for some time. Since 1762 we seem to have had no convulsion of nature more

intense than such earthquakes as that of 1897; the effects of that shock are not properly known; certain areas in the plains were certainly depressed, but how far these depressions were only due to local conditions of sub-soil, etc., we have no knowledge.

It was noticed after the earthquake of 1897, by several old and experienced Indigo Planters in North Bihar, that many minor streams, in and near the Siwaliks, changed their courses considerably; it is well known that in this region minor changes are not of infrequent occurrence, and that nature has not yet assigned anything like permanent levels to the Siwalik regions; at the same time she seems to be on the balancing point between secure and insecure levels. After the earthquake, the Nepal Durbar caused an enquiry into the changes in stream beds to be made, but unfortunately the records of the enquiry have not been preserved.

It is of no use to speculate further on the subject; if geologists had free access to the areas under discussion they might throw much light on the causes we search for; for instance, there must be clear signs of water wear on the rocks over which the Comla flowed 140 years ago; and again, an examination of the supposed old sill of the Dudh Kosi, for the name of that river implies a heavy silt-carrying capacity, and consequently severe rock-abraising power, might yield information that at one time a river had passed over what is now a dip in the Siwalik ranges. Surveyors, too, could throw light on the situation by measuring the heights of existing depressions in the Siwaliks above the present course of the western arm of the Kosi within the hills.

The past, present, and future history of that portion of the river lying within the hills has now been dealt with; its case is very different from that of the portion occupying the plains; in the hills the function of the river is to carry away, as fast as possible, all *débris* and matter it can pick up, carry, and push along, and also such material as it is able to transport in solution; the river is fed with matter to be transported in a number of ways, the details of which need not be entered into here; the chemical and mechanical denudation of the hills are the feeding agents, and a description of these two agents is outside the scope of this note. On reaching the plains, the river enters on a new phase of activity; in its mountain reaches it was destructive, but in the plains it is constructive in its action; the plains themselves are formed almost entirely by the river from deposits placed layer upon layer, deposits carried from the hills and built up by slow processes during many thousands of years. The plains section of the river is at the present moment engaged in construction work; at some future time, as will be seen later, its final life-object will be completed by the assumption of destructive action, during which stage, having first levelled its catchment area to the level of its plain area, it will, by slow degrees, reduce both to the level of the sea; until then the object with which nature originally created the river cannot be finally fulfilled; every river, except the mountain torrent which precipitates itself directly into the sea, into a large lake or another stream close to the hills, must pass through three stages of existence,

namely, its youth, during which it is destructive in its action, (the Kosi River in the hills), its middle age, or constructive stage (the Kosi in the plains, as we see it now), and, finally, its old age, or perhaps dotage is a better term, in which it again becomes destructive to the extent of eventually destroying itself. Earth movements may prolong any one stage for a period which to us is immeasurable, but the final result must be one, from the river's point of view, of self-annihilation.

The action of the river in its constructive stage is somewhat complicated; although definite laws are obeyed by every river under similar circumstances, there are certain points connected with these laws which, being often inexplicable to us, are classed together as the "character" of a river; for instance, if a river invariably carried the same amount of water, if its bed followed a slope which never varied, and if the soil, sand, or rock over which it passed were homogeneous and of the same material as its banks for its whole course, the river might fairly be classed as one with no individual character. Any variation, however slight it may be, from the perfect river just described, must introduce at least one element of character which may upset, at any moment, the calculations and plans of the greatest river expert living; fortunately for us, theoretically, the Kosi boasts of little personal character during the last 80 miles of its course, and, with one exception, its movements should be obedient to accepted rules. The exception is the actual reason for a sudden change of course, and it will be dealt with later on.

Immediately on the Indian side of the falls by which the Kosi enterst he plains, lies a comparatively steep-sided cone consisting of silt, rocks and *débris* ejected from the hills by the current of the river, but which the energy of the river has been insufficient to carry forward and deposit uniformly over the plains, or remove to the sea; the loss of energy is due to the sudden change in grade which, above the falls, is that of a mountain torrent and below them that of a comparatively sedate body of flowing water; through the alluvial cone the river runs in one main channel which may be considered to be semi-permanent; its permanency depends entirely on no change occurring at its debouching point, and, since that point is hedged in by hard rock, a semi-permanent channel at least may be accepted through the *débris* cone; if a very heavy fall of rock occurred on the east or west side of the gorge, which now leads the Kosi into its present path, changes of great magnitude might be anticipated, but as will be seen later, the longer time the plain-building operations of the river are permitted to go on as at present, the smaller will become the danger of a great and unexpected change of course. Rocks wear away so slowly by weathering, and building operations progress so comparatively rapidly, that each year renders sudden changes at this point more improbable. South of the cone the plains spread out on all sides awaiting the pleasure of the river to elevate them.

The action of a moving body of water over a sandy plain is

somewhat similar to that of a freshwater stream entering the sea; the effect of the latter at once gives a clue to the methods of the former; if a freshwater stream enters the sea at a given point, under ideal conditions, a "bar" will be formed; one cause of this bar is the deposition of the silt carried by the river; the velocity of the stream, which alone permitted the carrying of silt, is neutralized by the sea, and practically all material carried in suspension is dropped. In addition to carrying matter in suspension as already stated, the stream exerts part of its energy in rolling sand, and sometimes stones and boulders, along the bottom of its bed; these, in their turn, help to increase the size of the bar; if we apply the action of this bar-forming river to that of the Kosi in the plains, on which there is no sea to neutralize the flow, it is easy to see what must happen.

The first work of the Kosi is to roll along its bottom the stones which it is propelling, and with them as much other material as can be conveniently transported; the result is a somewhat steep bed until, with a decreased current, the power to roll material falls to a minimum; the river has then reached what we may look on as a normal of gradient; even then it will continue to roll matter along its bottom, but the further we get from the cone the smaller in bulk will be the matter rolled. All this time two other phases of actions are in progress; as the velocity of the current decreases, its suspension-carrying capacity becomes smaller and matter is steadily deposited in the bed, so that the bed becomes gradually raised. The other phase is one which I believe has not been sufficiently noticed by writers on the subject; it is a kind of ploughing action which tends to push to one side, and deposit there, a considerable amount of material which helps very greatly to form the unstable banks which all such rivers as the Kosi have. Here we see the parallel between water running into the sea and into a plain sand. In the former a bar was formed, in the latter the water continues to push forward, and incidentally to one side, all the material that it can, this material being that which, under different conditions, would have made up a bar.

If the processes described above are permitted to continue undisturbed for some years, the river, its bed and its banks, will, except at high flood, be raised well above the country on either side; at flood times the banks will, however, be overtopped by water, and a spill, great or small, according to circumstances, will inundate the surrounding country. These spill waters, coming to rest, deposit practically all the sediment they held in suspension, thus spreading a layer of sand or mud over the areas in which they operate; a gradual building-up of the low lands is thus effected.

Before proceeding to discuss the further reasons for the elevation of the plains, it will be well to enter further into the question of how the banks of the river elevate themselves; Fergusson, in a masterly note[1] read by him in 1863 before the

[1] Geological Society of London—Journal, 1863, p. 321—354.

Geological Society, considered that bank elevation, so far as the Ganges was concerned, was often due to the running water of the river at times of flood, meeting still "jheel" water at its sides, the result being that, since still water neutralizes a running current very rapidly, a heavy deposit was formed along the edge of the river; this explanation is undoubtedly correct in a limited number of cases, but, as a general explanation of the principle it fails utterly when applied to such rivers as the Kosi, which, with comparatively little still water on either side (for the slope of the country is too great to admit of water standing as freely as it does near the Ganges), steadily for the whole of their lengths, elevate their banks. Other writers give other reasons for this phenomenon, but none, I venture to think, meets the case of the Kosi so well as the ploughing theory given above. When once the bank is formed there are other agencies which tend to raise it still further, and one of these is particularly significant in the case of the Kosi River.

At about Longitude 87° East the force of the west winds which sweep Bihar from March until the monsoon bursts, begins to feel, in a very marked manner, the effect of the damp climate of Eastern Bengal; these winds, heavily laden with dust and sand, on meeting the first sign of a damp atmosphere begin to lose their strength, and, as in the case of a silt-laden river, the decreasd velocity causes the dropping of, at any rate, a part of the burden carried. It is probable that more deposit is dropped from the heavens in the neighbourhood of the Kosi River in the manner described above than in any equal area in the world; how far the banks are actually raised by this deposit, cannot be said, although it would not be difficult to obtain a tolerably accurate idea if a few simple field experiments were carried out. It must be remembered, however, that although a deposit occurs, the winds are still sufficiently strong to pick up as well as deposit, and it may be that much of the material dropped is picked up again. I cannot help thinking, however, that the action of the wind, if not constructive as a heightening agent, and I believe it to be constructive in that way, must tend to consolidate.
the banks of the river, since it must give them increased width.

There remain two other points which throw a considerable light on the building operations of the river; they are the effect of spill water deposits on undulating country, and the reasons for, and effect of, changes in bed on the country itself. Undulations in the area of operation of the river are, in all probability, entirely due to former changes in bed, and an important agent in smoothing them over is the deposit thrown down by spill waters. We will first examine the effect of spill water deposits on undulating tracts.

If spill waters cover an undulating country altogether, the deposit will be greatest where the water is deepest; it is therefore easy to see how low lands grow more rapidly than those situated at a greater elevation; a series of floods, consequently, may be looked on as capable of levelling altogether a slightly undulating area.

The waters are undoubtedly helped by wind and weather, but the main levelling agent must be the silt they carry.

It has been stated that changes in river bed are the probable causes of such undulations as occur in the neighbourhood of the Kosi River; the explanation of this is contrary to the views of many who have written on the subject, but to my mind it is so simple and logical, that I take the liberty of putting forward my own views.

Let us assume that the river has for some years occupied one bed and that it has raised that bed and its banks considerably; at a time of rising flood, a tree trunk, sunken boat, or some such obstacle becomes lodged in one bank of the river and forms, on its up-stream side, an eddy, which, since the banks are of sand, has no difficulty in eating a passage through the bank. When once a breach is effected, a change in the direction of the whole river may occur; let us assume this to be the case; the river, precipitated over the low lands on the side on which the breach has occurred, after doing an enormous amount of damage, eventually, let us say for argument's sake, takes a new course parallel to the old one, half a mile to the east; it is possible to conceive a series of such moves, which will leave ridges along which the river recently ran, and depressions between each two ridges, in which, for many centuries, no river bed has existed. In course of time winds, rain, spill waters and other agencies, not having had sufficient time to actually level the area, will turn it into an undulating tract in which the higher portions are the most recent river beds; eventually the turn of this undulating land comes round again and it is finally levelled and no trace of former depressions left.

At first sight this theory appears unreasonable. A little consideration will, however, show that there is nothing unreasonable in it, and that logically it is sound.

We have seen how, by operating in a series of beds over the whole area assigned to it, the Kosi gradually raises the level of that area, partly by heightening its successive beds, and partly by the action of its spill waters; the actual raising by these two joint agencies proceeds in obedience to a definite law which every constructive river in the world obeys. The law may be stated briefly as follows:—"A constructive river, by the deposition of its silt, gradually reduces its grade, or fall per mile, starting from the point most distant from its source and continuing the reduction in grade up stream"—the building up of the portion of British India involved has therefore commenced near the Ganges and is slowly invading the whole plain northwards, the rate of progress depending on many things which require some explanation.

Diagram No. 2 is somewhat similar to a diagram given by Fergusson in the note already referred to. It is a comparison between Rennell's survey and Survey of India maps up to date; the diagram shows that in 1780 the Ganges and Brahmaputra operated in certain areas in the plains; about a century later, very great changes have occurred, the Tista, instead of being a tribu-

tary of the Ganges, has become a feeder of the Brahmaputra, and the Brahmaputra, instead of running east of Dacca, has moved to the west; other changes will be noticed, but the two most important are those just referred to. Of these, the latter does not immediately affect the subject under discussion. Now, like the Kosi, the Ganges and Brahmaputra have, for centuries, been busy reducing their grades by the deposition of their silt; the plain of the Ganges slopes in a south-easterly direction until it meets the sea or the plain of the Brahmaputra; the sphere of the latter slopes, from where it crosses Longitude 90°, almost due south, and is bordered on the west by the plain of the Ganges. The land lying in the rectangle formed by Latitude 24° to 26° 20″, and Longitude 88° and 90°, is therefore liable to vary between the plain of the Ganges and its feeders, and that of the Brahmaputra and its tributaries, the main agent which causes a variation being a high flood. Diagram No. 2 illustrates the conflict which has raged between these two great rivers in the last 150 years. We have seen that the Brahmaputra, during that time, thanks to an unprecedented flood of the Tista, robbed the Ganges of the water of the Tista River. This piracy is very probably not the first of which the Tista has been the victim; it has, in all probability, in bygone days, alternated, at different periods, between the two master streams. Be this as it may, it seems to be not unlikely that the Brahmaputra has now finally become possessed of the Tista. Now the Kosi (old and new) has operated at different times over all the land between the debateable area along the junction of the Ganges and the Brahmaputra plains, and, roughly, Longitude 87° East; West of that Longitude and north of Latitude 26°, the land is tolerably high, but south of Latitude 26° there is an area some 30 miles wide, which is lowlying; in this low-lying area minor channels of the main Kosi are at present busy building up most of the depressions.

The sphere of action of the Kosi, then, since the Tista, Attri, and other rivers, before the Tista last returned to the Brahmaputra, apparently filled up fairly solidly everything east of Longitude 88°, may be defined roughly as a rectangle made by the intersections of Longitudes 87° and 88° and Latitudes 25° 20″, and 26° 20″ respectively; of this area all, except on each side of Longitude 87°, appears to have been dealt with by the Kosi in its older stages or by smaller streams issuing from the hills north of Purnea; the Kosi, therefore, is not likely to move appreciably either east or west of its present position. In the last 150 years the river has shifted slightly to the west, and its final point of entry into the Ganges may, I think, be safely put at less than 10 miles further west than the present Kosi bridge, the probability being that the move will be much smaller, but the final exit will not be known until the Himalayas are worn down to the approximate level of the plains. Changes must be expected, but great changes only if the river is trained by rigid embankments which prevent it temporarily from carrying out the work upon which it is engaged, which work it will assuredly, in spite of any effort of man, eventually perform.

The question of embankments has been raised at this point because there is the possibility of existing embankments inducing a change in the river to the east; it is even possible that the damage has already been done. This question is dealt with later on in this note. The estimate of probable movements given above is dependent on no sudden change in the depression of the plains taking place; if the depression ceases, no harm will be done; if it becomes more rapid than it now is, it is hopeless to attempt to anticipate the future. For instance, Oldham [1] and other authorities consider that the Ganges at one time flowed westwards to the Indus, or that the Indus once flowed into the Ganges. Again, Colonel Burrard has recently pointed out that the Sangpo [2] (Upper Brahmaputra) at one time, in all probability, flowed into the Indus; if a repetition of such things occurred the movements of the Kosi would be difficult to foretell! All that we can do is to assume that the rate of depression of the plains is constant, and that no changes such as those referred to will recur.

The main difficulty in estimating the rate at which the Kosi's building operations are progressing, lies in our lack of exact knowledge of the amount of depression now going on; we have neither guaged this rate nor that at which the Siwaliks are rising; between a rising Siwalik and a falling point in the plains, there must be some point which neither rises nor falls. If we could find such a point, or better still, a series of them, it would be possible to do something towards deciding this difficult question.[3] In this discussion I propose to eliminate the factor of depression altogether; as will be seen later, even if we eliminate what is quite probably the main argument in the calculation, it is possible to show that many centuries must elapse before rigid training works, on a large scale, will be advisable along the lower reaches of the Kosi River.

It has already been stated that the building operations of the Kosi commence near the point at which it enters the Ganges, but since that river is also engaged in land construction work, a complication at once arises in discovering how far north of the Ganges its silt-depositing sphere exists. What should, however, be a complication, has already been eliminated by the railway embankments of the Bengal and North-Western Railway; the Kosi passes below a bridge built by that railway, the railway line in prolongation of the bridge, on either side of it, running along an embankment which, for some distance, is roughly parallel to the Ganges. I believe that this embankment contains, from Mansi to Katihar, a direct distance of about 60 miles, an average waterway per mile of about 75 feet. If we cut out the waterway

[1] Oldham—Geology of India, Stratigraphical and Structural, Ch. XVII, p. 428.

[2] Burrard and Hayden—"Geography and Geology of the Himalaya Mountains and Tibet," Part III, p. 155.

[3] *Vide* page 51 of the Annual Report of the Board of Scientific Advice for India 1906-07; the effects of the 1905 earthquake on the height of Mussoorie are discussed by Mr. J. Eccles, M.A., Survey of India.

allowed for important streams (Chota Kosi, Boro, Barundi and Kosi), and these can be eliminated since they are not exits for Ganges water spilling to the north, we find that only just over 3 feet of waterway per mile remain for carrying Ganges spill through the embankment. In other words, the Ganges is not building at all north of the embankment. To me this embankment appears to be a "band" of the most dangerous type, namely, one which interferes unnecessarily with the work of Nature. During a journey made very recently from the west by the B. & N. W. Ry. I noticed the following points which, I hope, will show that the statement made above regarding he danger of the embankment is not without foundation; for some distance, before reaching the bridge, I noticed several depressions, on the north of the embankment, which were obviously beds of small streams. On reaching these I found that they were stopped altogether by the embankment, with the result that they could not, as they obviously did before the building of the embankment, carry their water to the Ganges; on the south of the embankment, in one case, there was absolutely no visible trace of the old bed, and in several other cases, although the old beds could be seen, they were very much less marked than on the north side of the embankment; this result is not due to the south side being cultivated and the north side uncultivated, but simply and solely to too little waterway for spill water from the Ganges being permitted to pass through the railway embankment; on the south side, the land is being raised rapidly by the Ganges, and on the north side little or no deposit is, in the place of which I speak, being given to the areas on the north, obviously legitimately within the sphere of the Ganges, but excluded from it by the railway embankment.

Let us turn to the south side of the Ganges. I have on several occasions searched that line for examples such as those just quoted, but so far without success; the reason is that although the E. I. Ry. was built at least 30 years before the B. & N. W. Ry., it was considered then that sufficient waterway [1] to admit flood water through the embankments was essential; in looking for the final result we find the south bank of the Ganges being raised as originally intended by nature, and the north bank suffering from a lack of deposit except along a narrow strip on the south of its railway embankment. After a limited number of years, a breach in the B. & N. W. R.y embankment may very possibly result in damage being done to others than those interested in the railway itself; the future can but give an increasing flood level to the Ganges at this point, and it seems quite probable that the action now going on will result in deterioration of the navigable channel of the Ganges further up stream.

[1] Excluding rivers, the linear waterway per mile between Mokameh and Bhagalpur is about 87 feet. I am aware that sectional comparisons, for waterway, are infinitely preferable to linear comparisons, but, since the E. I. Ry. embankments are higher than those of the B. & N. W. Ry., it is not necessary to give sectional areas of waterway when comparing the two railways in this note.

From the point of view of this paper, however, the limiting of the depositing sphere of the Ganges by the embankment on the north, simplifies the question under discussion, in that we need not take into account at all the Ganges as a depositing agent.

Before passing to the Kosi itself, the Ghuggri River remains to be dealt with; by far the greatest part of the water carried by this stream from its junction with the Kosi belongs to the latter. The Ghuggri as a depositing agent may be neglected also because its deposits are practically altogether made outside the sphere which we have assigned to the Kosi.

For all appreciable purposes, then, we may assume that the Kosi only has itself to depend upon to complete the forming of the ground on each side of it from the Kosi Bridge to a point 100 miles above it.

We do not, unfortunately, know anything definite regarding the silt-carrying capacity of the Kosi; any calculation made must be based on analogy. As far as I can ascertain, the two rivers most suited to the case, of which we have figures, are the Ganges and the Irrawady. Archibald Giekie gives the basin of the upper Ganges as 143,000 sq. miles, and the annual discharge of sediment as 6,368,077,440 cubic feet; according to Wheeler, a cubic foot of alluvial matter weighs between 120 and 170 pounds, while a cubic foot of silt weighs 103 pounds; since the Ganges and its affluents discharge a mixture of alluvial matter and silt in at present unknown proportions, I have, to reduce Geikie's sediment figures to tons, taken a cubic foot of sediment to weigh 120 lbs; this assumption gives the discharge of the Ganges as 341,147,050 tons of sediment per annum.

Babb estimates the Irrawady to have a basin of 125,000 sq. miles, with an annual sediment discharge of 291,430,000 tons; if we compare Geikie's and Babb's figures the sediment-carrying capacity of the Irrawady to the Ganges is as 2·33 to 2·38, and considering the similarity of the two rivers, we may, I think, accept Geikie's figures as sufficiently correct for the purposes of the rough calculation given below.

The Kosi has no feeders of any importance outside its catchment area, which is roughly 24,000 sq. miles; the river, therefore, if it is the counterpart of the Ganges and Irrawady, carries approximately 55 millions of tons of sediment per annum; of this amount probably not more than one half is used in building operations. I assume, to be on the safe side, that two-thirds, or about 37 millions of tons, are deposited annually on the lands to the sides of the river; 37 millions of tons of sediment are the equivalent of 691 millions of cubic feet.

Now the actual slope in the bed of the Ganges for the last 300 miles of its course, measured in a straight line, is about 6 inches per mile, a low grade even for a canal; during those 300 miles the river is by no means a tractable stream. The object of this calculation is to show what minimum period of time must elapse before the Kosi River will be as far advanced in age, in

other words in want of tractability, as the lower Ganges is at the present moment; the slope of the bed of the Kosi River, measured along a straight line, is between 1 foot and 18 inches per mile. For the purposes of calculation, let us accept the former; the area on which the Kosi deposits its silt is probably on an average at least 20 miles wide; if we accept a strip of 5 miles on each side as the area on which deposition will occur, we must err on the right side in our calculation; in other words, we assume that the area to be raised is 100 miles in length, and 10 miles in breadth. If from the above figures we calculate the time which must elapse for the slope of the 100 miles of the Kosi under discussion to average 6 inches per mile, we shall find that about 1,000 years is the answer to the calculation. I admit the figures I have accepted are not based on the results of observations, but, notwithstanding this, they give not un-interesting results.

The period is, in all probability, much shorter than that which will actually elapse before the Kosi reaches as forward a state as the lower Ganges is in to-day; exaggerated figures have been used in the calculation and the depression of the plains has been entirely neglected; if the depression equals the building power of the river, matters will remain stationary until one side proceeds faster than the other. From a human point of view, therefore, if we assume that the plains are still sinking, our estimate may be multiplied with absolute safety, by infinity. From the above, it will, I think, be agreed that the time has not yet come for the rigid training of the Kosi River.

Before any practical attempt can be made to save those areas in Purnea and Bhagalpur from the ravages of the Kosi, a considerable amount of enquiry is necessary; this enquiry will entail certain field work. Below is given a series of items about which full information will be required:—

(1) Two cross sections of the river surveyed normally to the current, one at a point as close to the exit from the Siwaliks as possible, and another at the railway bridge; the latter may be obtainable from the B. & N. W. Ry. authorities. If possible, a third section should be measured midway between the two just mentioned.

(2) At each section, measurements of (*a*) changes in bed, (*b*) rate of current; (*c*) amount of silt carried; (*d*) chemical examination of silt carried at different phases of flood level of the stream, should be made for at least one year. (*a*) Should be taken monthly; (*b*) and (*c*) daily at a given time; and (*d*) at all differences of height of stream at intervals of 6-inch changes.

(3) From data already described, the mean annual discharge of the river (*a*) in water, (*b*) in silt, should be computed.

(4) The rate at which the plains are being depressed and the Siwaliks raised, should be found experimentally; this will entail the discovery of several points which lie between the Siwaliks and their complement, the plains which do not alter in altitude. If several lines of really careful levels were run in such a way as to converge from masonry points on the hills on the south side of the

Ganges on to a known high point in the Siwaliks, the checking of these levels annually would, in a few years' time, give a very fair idea of what points had remained stationary; there are factors in this calculation which would tend to vitiate the final result, but a sufficiently accurate idea could be obtained to be of practical value. In addition to the one point in the Siwaliks mentioned above, others should be fixed and observed to. If sufficiently long lines across the plains were run, the actual subsidence could be computed in cubic feet, but if annual changes were too small to be noticeable, the operation should be continued for a series of years.

The two main points which would vitiate the results are: (*a*) the amount of annual denudation of the Siwaliks due to weathering; this might be eliminated, unless it is a negligible quantity, and this it probably is, by carefully protecting from the weather the points observed to; (*b*) the effect of the deflection of a plumb line from the normal owing to the proximity of the mass of the Himalayas. For this, with present knowledge, an approximate correction, sufficiently accurate for all practical purposes, might be utilized.

(5) The effects of the Ganges flooding before the Kosi, and *vice versâ*, must be observed; in the former case it would be necessary to discover how far up stream the waters of the Kosi and Ghuggri were dammed up; to what extent excess deposits through spill waters in the area outside the beds were induced, and how far the releasing of the Kosi's waters affected the bed of the river.

(6) Other information would be required, such as the water and silt-carrying capacity of the Ghuggri which would have to be deducted from discharges computed in (3) above. Another example is the finding, by levels, of the fall per mile of the bed of the stream.

(7) If the existing maps are not sufficiently recent, a careful survey should be made showing all details of minor streams, low-lying areas, and existing embankments with details of waterway (if any) allowed through them.

Although the field work outlined above is not by any means an exhaustive statement of all that might be required, its compilation would give a very fair idea of what alleviation for those who, at present, bear the brunt of devastating floods, might be possible. Until this work is carried out, and carried out with the utmost care, it is impossible to say whether or not any means of alleviation are at present advisable. In the above, the enquiry regarding para 4 (rate of elevation and depression of the Siwaliks and plains respectively) might perhaps be postponed; if it is postponed, then levels must be run from side to side of the area of operation of the river or insufficient information will be collected.

The relief to those affected by the floods of the river must take one or both of two forms: either embankments must be erected with such an amount of waterway through them that the river will not be hindered from carrying out its programme of

land construction; or else the Italian system of Bonificazione (artificial land construction) must be resorted to.

The former will necessarily mean that at times of heavy flood the interests of those for whom embankments have been constructed must be sacrificed in the interests of posterity; crops must probably be ruined if the river would have flooded them if unconfined, and a state of affairs brought about by Government which would be liable to grave misunderstanding from those who, accustomed to look upon an embankment as a protection against the loss of their crops, find, on occasion, that, to their uneducated minds, the embankment is in itself a menace; although, if careful discrimination is used, it is quite possible to do much to alleviate the lot of those at present in difficulties, it is extremely doubtful if even a really well-devised system of "bands" would be administratively advisable.

The Italian system might perhaps be used; briefly stated, it consists of the running of silt-laden waters into low-lying areas in such a manner that, after the water has come to rest and the silt been deposited, the water can be run off. A detailed description of this system was given in a note read before the Arts Society in London some short time ago by Sir Edward Buck, K.C.S.I. The system is doubtless excellent, if a careful chemical examination of the silt carried at certain heights of rising or falling flood is known, and if the fall of the river and surrounding country is sufficient to permit of the water admitted to low lands being run off by gravitation after it has performed the work intended to be obtained from it. In the case of the Kosi, it is possible that much might be done by this system, but without accurate levels it is not possible to say how far Italian methods can be copied. Sir Edward Buck advocates a proper enquiry into the system of Bonificazione as applicable to India, and, although, before he left India, he made careful enquiries into the amount of artificial fertilization by silt, and was in a position to expect to obtain full answers to his enquiries, it is very significant to notice that the case of Chota Nagpur (where a form of Bonificazione has been practised probably for many centuries, and where it is perhaps more actively used than anywhere else in India) has no place in Sir Edward's able note. The traveller in Chota Nagpur cannot but notice the quaint way in which rice lands collect on each side of the "nalas" in undulating country; the running water is directed down the centre of the depression and is capable of deflection into any "*kiari*," or sub-field, at will; the silt of the stream is thus deposited where wanted, without any difficulty; Sir Edward briefly reviews the different methods reported to him by Indian officials in his paper, and since no mention is made of the Chota Nagpur system it must be assumed that the officials in those parts had, at the time of enquiry, failed to notice it. The case is quoted at some length here since it shows that, from the methods of an Indian race only half emerged from savagery, we may learn at any rate some of the elements of one system which is perhaps applicable to the mitigating of the evil-doing of the Kosi River.

I admit that, owing to greater declivity of bed, the Chota Nagpur streams are not a true parallel with such rivers as the Kosi, and also that Bonificazione is only practical in the reaches of streams whose bottoms are not visibly rocky; at the same time it must be admitted that lessons are to be learnt from the methods of the Chota Nagpuris.

The Kosi River is really only of local interest; the examination so far made in this note, however, leads to questions of more general importance; although the Kosi cannot be called navigable to-day, the time will come when it will be so; that time will probably not be until the Himalayas almost disappear. As soon as the bed of the river approximates a slope of six inches to the mile, it will assuredly then be capable of being navigable, and it is not improbable that this happy state of affairs may arise with a bed of somewhat greater declivity; with a slope in bed of six inches to four inches to the mile, when that grade is *first* reached, a river may, I think, be considered to have attained mature middle age; as the slope decreases beyond that limit, in the case of rivers running through country formed by their own deposits, after passing the transitional state between old middle age and young old age, old age actually sets in and the action of the river changes; despite a reduced grade, and one which has fallen almost to a minimum, the river begins to deepen its channel. This is the second real sign of self-destruction; the first sign is to be observed during the transitional stage. After raising the surrounding country as far as possible, the river must begin to think about destroying the work which it has been engaged upon for many centuries: in doing this it is forced into a fixed bed, but, before that bed becomes actually permanent, since the country through which the river flows is very little different from a flat surface and its consistency is homogeneous, it naturally flows in a wide and shallow stream, and later, by a series of contractions, due to the actual middle of the stream beginning to eat away a suitable bed, a final and winding course is decided upon and maintained.

It is thought by some that the lower reaches of the Ganges are bordering on the transitional state at the present moment; the river, for some reason, appears at times to be more shallow than it used to be; it is not impossible that the Ganges hopes shortly to assume a permanent bed, but, if modern theories are of any value, and they are based on carefully recorded experience in many parts of the world, we have only to look at the Himalayas to obtain the correct answer. According to Russell,[1] in round numbers, the basin of the Mississippi is being reduced in height at the rate of one foot in about 4,000 years; this degradation includes both mechanical and chemical action; and before the Mississippi, the Tista, the Kosi, or any other similarly-situated river can be said to have reached a transitional stage, the height of the Himalayas must have been considerably reduced; these

[1] See page 84 of Professor Russell's River Development.

rivers must be constructive in their lower reaches until they have practically levelled to their plain elevation the mountains from which they collect their water, and with their water their silt. This being so, we cannot expect the Ganges (below Benares) and the Brahmaputra (throughout British Territory) to reach a stage at which they are likely to be permanently navigable without artificial help for a considerable time to come; it is pleasant to anticipate that at some period, assuming that climatic conditions remain unchanged, the Himalayas will be an undulating country more suited as a retiring ground for Anglo-Indians than any place we can imagine. This acme of perfection is, however, far ahead of us, but until it is somewhat close at hand, we cannot expect our rivers to be naturally navigable; at present Nature, with the forethought which all of us unhesitatingly allow to be her crowning virtue, is busily engaged in a struggle with the rivers themselves to prevent them becoming navigable, or to frustrate their suicidal efforts to avoid the work which they have got to carry through, and we may confidently anticipate that Nature will win the day. Nature wishes to prevent the assumption of a permanent bed which by degrees will contract; to present-day river navigation a permanent bed is not an essential, and we shall not thwart Nature in any way by keeping open by dredging, or other measures, the changeable channels of the Ganges and Brahmaputra.

The Ganges and the Brahmaputra are both, within limits, at the present moment, navigable up to certain points. With regard to the former, since she is practically hedged in by railways on either side for the greater part of her length, it may be argued that the keeping open of steamer ways is of no great importance; at the same time, the paralysing effects of the recent strike on the East Indian Railway, which for a considerable distance follows the Ganges, suggests the grave necessity of due attention being paid to that river as a transport medium; if steamer lines had existed on the Ganges to the extent to which they might have existed, there is little doubt but that the effects of the strike would have been less paralysing.

It has been here assumed that railway transport, if available, is always preferable to river transport; the assumption is a wrong one and it should be remembered that for many articles water is preferable to railroad carriage. Continental and other nations are rapidly, at the present moment, increasing their lines of canals and improving their river channels for that very reason, and so seriously is the necessity for efficient water transport recognised, that canal dues are being rapidly abolished; as the old road toll bar levies disappeared, so canal dues must go to the wall, and the school which maintained that the introduction of railways was the death-knell of canals, has, in civilized countries, long since been recognised to have preached unsound doctrine. We may therefore take it that, if at reasonable expense we can, without upsetting the balance of Nature's arrangements, keep the Ganges open for low-draught steamer vessels throughout the year, it is

essential, in the interests of the advancement of the inhabitants of the Gangetic Plain, that the requisite expenditure should not be grudged.

The case of the Brahmaputra is, however, still more important than that of the Ganges; this river, in its whole length in British Territory, is, as a public highway, of the utmost importance at present, and yet nothing, except by private enterprise, is being done to improve its navigation. River steamers stick on sand banks for hours, and sometimes for days, when, by the copying of American methods, the obstacles which cause all the delay described can, at small cost, be done away with.

In making such statements as those just made, I do not intend to criticise the attitude of Government; the records of the tours of Sir Lancelot Hare, Lieutenant-Governor, E. B. & Assam, for the last year, show clearly the sympathy he feels with those incommoded by the action of the rivers of his Province, and the wish he invariably expresses for applicants to be patient and to give the Government full time for consideration of such an important subject, speaks for itself. To rush into the attempted adjustment of the complications of nature's machinery would be unwise, and all concerned should clearly recognise that, without considerable delay, any attempt to deal with the question wholesale would be an unsound, if not a positively dangerous, policy. Already there are signs that Government intends acting as soon as possible, and when action is taken a vast stride in the advancement of North Eastern India will have been made.

Whatever the changes are which are going on in the levels of the channels of the Ganges and Brahmaputra, they are proceeding very slowly, and anything that can be done to improve those channels, although it will involve work year by year, may be looked on as labour which, although it may not have a permanent result, will help materially to improve our own communications, and, if continued, those of future generations.

In our inquiry into the possibility of training these rivers there are two final objects which require to be borne in mind: (*a*) the improvement of low water channels; (*b*) the protection of country from floods. It has already been shown that wholesale protection from floods is either inadvisable or impracticable. The provision of suitable embankments may, I think, for reasons already given, be dismissed as a general plan of alleviation; the possible courses open to us are at once narrowed down to—(*a*) dredging; and (*b*) contraction of the stream by "*bandals*" or some similar method.

Bandals are screens of mats and bamboos placed across the sides of wide and shallow beds in such a way that a series of such screens breaks the force of the current to the extent of forcing it to deposit silt in suitable places, places in which it would otherwise not deposit; the current in the middle of a shallow reach can be thus accelerated, and a deeper bed maintained at lower water. Bandals can be made to carry out two main kinds of work—(*a*) bank consolidation; and (*b*) channel deepening; the case of

the bank is dealt with by compelling the main stream to keep away from the banks and so preventing it from eating away the sand of which they are generally composed; bandals are a true imitation of the methods of nature; they cost little, are efficacious, and, for our Indian rivers, are probably the most suitable means of river training which we could adopt. American experience, however, teaches that the forced deposition of silt does not tend to improve channels appreciably if the slope in the bed is less than ·4 feet per mile; at the same time, it is not impossible that the banks of streams whose grades are less than ·4 feet per mile could be protected somewhat by the bandal system.

Speaking roughly then, our scheme for treating the Ganges and Brahmaputra should take the following lines:—Where grades are 5 inches per mile and less, channels should be improved by the use of hydraulic dredgers; where grades are greater, bandals should be used— (*a*) to contract and so deepen channels; and (*b*) (which in many cases would be included in (*a*)), to consolidate or to prevent unstable banks being eaten away. Finally in the lower reaches in which Hydraulic dredgers would be used, the improvement of banks would be made, after careful enquiry, by bandals where possible, and occasionally protective embankments which would not be designed to stop spill water of any but the lowest of high floods.

One other point only remains for consideration, *viz.*, the question of lighting rivers for night traffic, for without lights an expeditious service is impossible. At present, except in times of fog, the Brahmaputra is navigated by steamers both by day and night; the lighting is done by the company owning the steamers used, and such bandalling as exists is also done at the expense of that company; the freight rates by steamers are considerably lower than railway rates, but they could, I believe, be still further lowered if the lighting and keeping open of the channels was not done at the expense of private enterprise. At present, as has already been stated, nearly every civilized nation in the world is busy improving its waterways at the expense of the State, and the abolition of dues for this work is proceeding apace. India alone hangs back, although her possibilities are far ahead of those of most other countries. For years the question of the improvement of the Indus has been under discussion; seven years ago Dawson published his notes on the Mississippi River and showed how the methods of American engineers could be copied with advantage in India. Dawson has, unfortunately, since died, but his able book still stands as a monument of careful work and careful study, and shows us, in India, how very far we are behind the times.

Mr. Lees has shown that by moderate expenditure the water routes from Calcutta to Eastern Bengal, Assam, and the United Provinces can be enormously curtailed, but so far, very little action appears to have been taken on his suggestions.

The examination of the Kosi River which we have made has shown that there is much to be learnt by studying the movements and causes of movements of the river. There are, however, a

number of other matters which might have been included in this note, but, as they will involve an examination of the Sunderbans tract, and the application of its methods of formation to those of such rivers as the Kosi, it has been thought best to postpone further discussion on those points until a future date.

In conclusion, I may add that it is with considerable diffidence that I have written this note. I am an amateur student of the subject, and my practical experience is limited to some seven year's observation of large rivers in Bengal and Eastern Bengal, at such times as my work has called me to visit them. At the same time, since the questions raised appear to have received so much less attention then they deserve, I have, after much hesitation, made bold to place my views on paper. There are many with a better knowledge of the subject than I, who will disagree with much that this note contains: if my comments are capable of raising a proper discussion amongst those competent to criticise them, the object of my simple effort will be partially fulfilled. If such a discussion ends in the questions being dealt with practically, that object will be amply fulfilled.